Attachment F – Benefit-Cost Analysis

Commonwealth of Massachusetts

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1. Process for Preparing the Benefit-Cost Analysis

This benefit-cost analysis (BCA) has been prepared for the Commonwealth of Massachusetts' proposed "Plant a Tree" project, which is described in detail in Exhibit E – Soundness of Approach. This BCA was prepared by AECOM in close coordination with the Commonwealth. The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) developed the project costs using a variety of resources, including detailed budget information from the existing statewide tree planting program called Greening the Gateway Cities Program (GGCP; http://www.mass.gov/eea/pr-2015/greening-the-gateway-cities-program-expanded.html) that involves planting trees in low income urban neighborhoods, and tree box filter unit cost information from the United States Environmental Protection Agency (USEPA) (USEPA Report Link). AECOM developed the benefits of the project by conducting literature review, research, and using benefit estimating tools such as the National Tree Benefit Calculator (http://www.treebenefits.com/calculator/), which is based on the United States Department of Agriculture (USDA) Forest Service's peer-reviewed i-Tree software suite (http://www.itreetools.org/). The identified benefits and costs were quantified where possible, and those benefits and costs that are difficult to quantify or monetize were qualitatively discussed. The BCA resulted in development of a benefit-cost ration (BCR) for the project.

2. Full Proposal Cost

Table 1 and Table 2 present the costs of the Tree Planting project. The costs reported in Table 1 reflect all aspects of purchase, installation, and watering costs for the tree plantings, and the costs reported in Table 2 include all aspects of design, installation, and operations and maintenance costs for the tree box filters. A total of $2.79 million in CDBG-NDR funds is requested for public property right of way plantings and tree box filter installations, and $2.78

million in other funds secured by EEA will be used for plantings on private property, for a total project cost of $5.67 million. Additional detail on project costs is included in Exhibit E – Soundness of Approach.

Table 1. Tree Planting Costs

Community	No. of Public Trees (40% of trees - HUD)	No. of Private Trees (60% of trees - EEA)	Total No. of Trees	Public Tree Planting Cost (HUD)	Private Tree Planting Cost (EEA)	Total Cost
Greenfield	386	579	965	$366,700	$332,925	$699,625
Springfield	2,834	4,251	7,085	$1,894,550	$2,444,325	$4,338,875
TOTAL	3,220	4,830	8,050	$2,261,250	$2,777,250	$5,038,500

Table 2. Tree Box Filter Costs

Community	No. of Tree Box Filters	Cost (HUD)
Greenfield	12	$141,432
Springfield	25	$389,650
TOTAL	37	$531,082

3. Current Situation and Problem to be Solved

The tornadoes that ripped through Springfield in 2011 destroyed approximately 7,500 trees, which dramatically reduced the canopy cover in portions of the city and eliminated the environmental, social, and economic benefits these trees provided. The City of Greenfield, which is located in the Deerfield River watershed, was heavily impacted by Hurricane Irene. Primary impacts from this natural disaster were related to flooding and stormwater, but several trees were also destroyed in the city.

Hurricane Irene resulted in significant stormwater damages to both Greenfield and Springfield. As precipitation and the number of storms will increase with climate change, the stormwater benefits resulting from this proposed project will help reduce future flooding and related pollution- and erosion-related impacts and serve as a model for justification of installing more tree box filters throughout Springfield and Greenfield where urban neighborhoods drain to the Connecticut River. For example, each tree box filter will reduce annual runoff by approximately 25,000 gallons (http://cals.arizona.edu/cochise/waterwise/waterharvest.html) and each tree box filter will remove the following percentage of pollutants (Houlem, James J., Puls, Timothy A., and Thomas P. Ballestero 2012 Performance Evaluation Report of the Portsmouth Tree Box Filter Treatment Unit Univ. of NH Stormwater Center) – TSS (82%), TPH (71%), TZn (93%) and TP (52%).

The trees and tree box filters will reduce stormwater flows within the developed downtown areas. The investment in public trees and tree box filters will be returned in reduced stormwater and combined sewer overflow treatment costs (Deutsch, B., et al., 2007). In addition, planting trees will reduce impacts to housing and infrastructure due to hurricanes and tornadoes. A co-benefit is that trees will save summer and winter energy costs, reduce the urban heat island effect which is being amplified by climate change, and reduce peak heat days and the associated health impacts for the elderly and vulnerable populations that live in these downtown neighborhoods. The number of days above 90 degrees is projected to increase significantly in future decades and will have an inordinate impact on low income residents of these downtown areas. Tree planting will also increase the resilience of the urban canopy in the two cities which are currently composed of scattered, aging trees of very few species (majority are Norway Maples which are highly vulnerable to the Asian Longhorn Beetle and other invasive species). It will increase the species and age diversity of the urban forest, making it more resilient to future pest and storm impacts, and allow the neighborhoods to retain more tree cover after significant hurricane wind events.

The entire cities of Greenfield and Springfield are considered low and moderate income (LMI) area. The vulnerable LMI populations in both cities will benefit from reduced flooding, reduced pollution in nearby waters, reduced risk of high wind, and reduced costs of cooling and heating. The model for planting trees in urban low income neighborhoods has been proven in the following cities through the state's existing GGCP program: Worcester, Chelsea, Fall River, Revere, and Chicopee.

4. Proposal Description

The Commonwealth has an existing statewide GCCP (GGCP Spring 2015 Report Link), which is an environmental and energy efficiency program designed to reduce household heating and cooling energy use by increasing tree canopy cover in urban residential areas in the state's Gateway Cities (http://www.mass.gov/hed/community/planning/gateway-cities-and-program-information.html). GGCP is a partnership between EEA, the Department of Conservation and Recreation (DCR), the Department of Energy Resources (DOER), and the Department of Housing and Community Development (DHCD), along with Gateway Cities and local grassroots organizations. The program plants new trees, with a goal of covering 10% of the target neighborhoods in new tree canopy cover to achieve reductions in energy needs for cooling and heating resulting from the increased tree canopy, which lowers wind speeds, provides shade, and reduces summertime air temperature. The GGCP is a unique way to reduce energy costs for LMI residents and has developed a fine-tuned process where tenants request trees and agree to provide watering for two years and get sign-off from landlords for plantings.

The Plant a Tree project proposed by the Commonwealth in this Phase 2 application will expand and enhance the GCCP by securing additional funds to target and prioritize tree plantings in LMI neighborhoods in Massachusetts communities, specifically Springfield and Greenfield, and also incorporate installation of tree box filters (which are not in the scope of the GCCP) to achieve additional stormwater benefits. The key objectives of this program include:

- Replacing trees that were destroyed by natural disasters
- Making urban neighborhoods more resilient to future disasters by increasing tree canopy and the presence of green infrastructure
- Reducing energy costs for LMI populations
- Training local residents and creating urban forestry jobs

The Plant a Tree project consists of two main activities: 1) greening urban LMI neighborhoods through the planting of trees in public rights-of-way and on other public properties, and 2) the installation of tree box filters. The tree planting in Springfield and Greenfield will be carried out by two 11-person crews (each crew includes two foresters who supervise the crew and conduct outreach meetings with the community, city officials, neighborhood associations, and residents). Approximately 3,220 public trees will be planted by the two crews within a two year period using the requested HUD funds, and approximately 4,830 private trees will be planted in the following three years using other funds secured by the state.

The tree box filter activity includes planting of additional trees with tree box filters in key public locations to address stormwater runoff in Springfield and Greenfield and aid in reducing combined sewer overflows in Springfield. A total of 37 tree box filters are proposed: 25 in Springfield and 12 in Greenfield. The tree box filters will be installed concurrent with the two years of public tree planting.

The estimated useful life of the trees planted by this project is 50 years, and the estimated useful life of the tree box filters is 25 years. The base-case discount rate in Office of

Management and Budget (OMB) Circular A-94 (7%) was used for the BCA analysis. An alternative discount rate of 3% was also used for comparison following guidance from HUD and OMB.

5. Risk if Proposal is Not Implemented

If the Plant a Tree project is not implemented, the cities of Springfield and Greenfield will not have a strengthened natural line of defense against future tornado and flood disasters. Without the proposed tree plantings, wind speeds will continue to be higher for the affected LMI areas. Measurement of wind speed (a good proxy for heating energy demand by older, poorly-insulated houses) in Springfield following destruction of trees as a result of the 2011 tornadoes, indicated a 66% increase in wind speed compared to baseline conditions when the trees existed (Morzuch 2013). Stormwater runoff will be greater during storm events since there will be less vegetation. Trees promote evapotranspiration and interception (trees hold hundreds of gallons of water in their canopy that evaporates instead of landing on pavement and lawns and becoming stormwater) of stormwater that would otherwise run off into local streams, and each tree box filter installation is the equivalent of removing 1,000 square feet of pavement in terms of stormwater flow and treatment reductions (USEPA 2015). Climate change is expected to result in increases in the frequency and intensity of storm events for Massachusetts, so the current risks are only expected to be greater in the future. Furthermore, energy savings to LMI residents and new urban forestry jobs that are anticipated as a result of implementation of this project would not be realized, resulting in lost opportunity economic benefits from cost savings to vulnerable populations and job creation.

6. Categories of Costs and Benefits

6.1 Benefit-Cost Analysis Overview

The project assumes that approximately 3,200 public trees (without tree box filter) will be planted over the course of a two-year period beginning in 2016. The BCA analysis assumes that 50% of the trees are planted in the first year and 50% are planted in the second year.

Table 3. Quantity and Location of Trees

Community	Total Trees	Distribution
Greenfield	386	12%
Springfield	2,834	88%
TOTAL	3,220	100%

Five types of genus will be planted (see Table 4). The analysis assumes that the distribution of type of genus is the same for Springfield and Greenfield. In addition, 37 tree box filters will be planted, with 25 planted in Springfield and 12 planted in Greenfield (see Table 5).

Table 4. Proposed Types of Trees and Growth Rates

Genus	Number of Trees	Growth per year		Distribution
Acer	309	0.33	inch	27.9%
Quercus	266	0.32	inch	24.0%
Carpinus	214	0.23	inch	19.3%
Prunus	163	0.67	inch	14.7%
Cornus	156	0.34	inch	14.1%

Table 5. Proposed Tree Box Filters

Community	Number of Tree Box Filters
Springfield	25
Greenfield	12
TOTAL	37

The analysis assumes a survival rate of 80% within the first two years of planting (10% do not survive in the first year and 10% do not survive in the second year). After the second year, the analysis assumes the tree will survive.

Based on the diameter at breast height (DBH) of the tree at planting (one inch) and the rate of growth of each genus of tree per year, the analysis estimates the stormwater, electricity, air quality, property value, natural gas, and CO_2 benefits for each incremental increase in diameter per year over a 31 year analysis period (30 years of benefits for the trees that are planted in the second year)[1].

The costs incurred over the analysis period are the capital costs of purchasing and planting trees and tree box filters and the operating and maintenance cost of watering the trees for the first two years after planting. Pruning costs are negligible. The cost per tree is identified in Table 6. The cost of installing a tree box filter is $11,786, and this includes the cost of the tree for the tree box. The discounted stream of costs equals $1,197,200 ($2015) and $1,293,400 ($2015) at a 7% and 3% discount rate respectively.

[1] Treebenefits.com/calculator, accessed October 8, 2015.

Table 6. Average Tree Cost

Cost of planting a tree (no tree box)	Public Cost per tree	Private Cost per tree	Average cost of planting a tree
Greenfield	$950	$575	$725.0
Springfield	$575	$575	$575.0

The BCA analysis estimates three types of benefits: resiliency, environmental, and social. These benefits are summarized below.

Resiliency Benefits

Resiliency benefits look at the benefits of stormwater reduction and the reduction in energy consumption (electricity and natural gas) from tree cover. The tree box filters result in an additional benefit from a reduction in stormwater flooding. The discounted stream of benefits equals $529,300 ($2015) and $1,082,500 ($2015) at the 7% and 3% discount rate respectively.

Environmental Benefits

Environmental benefits look at the reduction in carbon dioxide over the analysis period, assuming an increase in carbon dioxide reductions as the tree grows. The discounted stream of benefits equals $9,200 ($2015) and $19,100 ($2015) at the 7% and 3% discount rate respectively.

Social Benefits

Social benefits look at improvements in air quality and the increase to property value from planting trees. The discounted stream of benefits equals $1,062,700 ($2015) and $1,876,200 ($2015) at the 7% and 3% discount rate respectively.

6.2 Benefit-Cost Analysis Conclusion

The program will yield a positive net present value discounted both 7% and 3% over the analysis period. The program yields a benefit cost ratio of 1.3 and 2.3 at the 7% and 3% discount rates, respectively, as shown in Table 7.

Table 7. Net Present Value and Benefit-Cost Ratio Results

Metric	7% Discount Rate	3% Discount Rate
Net Present Value	$404,001	$1,684,398
Benefit-Cost Ratio	1.3	2.3

6.3 Qualitative Benefits Discussion

Increased tree density in urban communities can have several positive environmental effects. Through their natural metabolizing processes, trees reduce the effects of harmful automobile and industrial exhaust fumes, which can be a major public health concern in urban environments. Carbon monoxide, sulphur dioxide, nitrogen oxide, and particulate matter are all toxic components of automobile emissions. These toxins are associated with fatal health conditions including stroke, lung disease, heart cancer, asthma, and respiratory infections. According to the World Health Organization (WHO), air pollution caused 3.7 million premature deaths globally in 2012 (WHO 2015). Trees significantly reduce toxic compounds in the atmosphere by absorbing large quantities of the pollutants and filtering out these toxins from the air. The *Journal of Epidemiology and Community Health* reported that childhood asthma rates decreased by 25% for every 340 trees per square kilometer (Lovasi 2008). According to the Center for Urban Forest Research, the tree canopy of Houston, TX removes an estimated 60,575 tons of air pollutants annually, which is valued at $300 million in associated health costs (McPherson 2006). Additionally, urban trees in Los Angeles, CA annually remove about 77,000 tons of carbon from the atmosphere and about 1,976 tons of air pollution (Nowak 2011).

An increase in trees can also improve stormwater absorption and decrease the need for drainage infrastructure. Trees absorb the initial 30% of liquid precipitation through their leaf systems and up to an additional 30% through their root systems (Burden 2006). A mature tree can store from 50 to 100 gallons of water during larger storms. The remaining precipitation seeps into the groundwater or becomes stormwater runoff, which can cause significant flooding damage to urban infrastructure as well as soil environments. Runoff can deplete soils of essential nutrients and cause erosion of soiled foundations. Trees reduce the need for drainage infrastructure and degradation of soil environments by reducing annual stormwater runoff by 2-7%. (Fazio 2010) Stormwater runoff can also have negative effects on sewage volumes and cause sewer overflow. In the sewage and water department of Detroit, incorporating trees and green infrastructure practices reduced overflow volumes by 10-20% and reduced annual costs by $159 million a year (Berkooz 2011).

In urban environments, trees provide protection from the elements to both people and paved surfaces. Between tree shaded and non-shaded areas, there can be a 5-15 degree difference in temperature. Paved surfaces can increase urban temperatures up to 7 degrees, leading to higher energy costs for both residential and commercial properties. (Burden 2006) Trees aligning residential or commercial streets can reduce energy bills up from 15-35%. Additionally, trees can prolong the life of pavement by up to 60%. The daily heating and cooling of these surfaces, combined with the seasonal changes, causes expansions and contractions of the pavement. Over time, this movement creates major cracks and fissures in the asphalt, which are safety hazards to both pedestrians and motorists that need regular maintenance. Trees reduce the surface's exposure to the elements and thus reduce maintenance costs of paved spaces.

Increased tree density in urban communities can also improve mental health of residents. The *Journal of Attention Disorders* examined the effects of environments on children with ADHD, comparing time spent in treed spaces against non-treed downtown and residential areas. Results determined that 20 minutes in a natural park setting improved the concentration and focus of the children to the same degree that ADHD medication affected children in the urban and residential settings, concluding that time spent in a natural setting could be used as a safer and less expensive alternative to medication (Taylor 2008). Increasing tree density and incorporating more natural elements into urban areas could help residents who struggle with attention and focus.

Improved mental functioning associated with greater tree density also applies to the work force. The University of Michigan examined the impacts of greener environments on worker productivity and determined that employees without views of nature and trees from their desk claimed 23% more sick days than those with views of nature and trees.

Finally, trees create safer spaces for both pedestrians and motorists and have aesthetical benefits in urban areas. Tree-lined streets create more focused driving environments for motorists and safer walking areas for pedestrians. Correctly situated, trees effectively create a vertical framing that provides drivers with a well-defined boundary within which to focus, reducing accident-causing distractions. Additionally, trees aligning streets provide motorists with a method to gauge their speed. By comparing their speed against stationary trees, motorists are more aware of their speed and have a tendency to drive slower along a treed street.

The framing created by the trees for the motorists also provides protection to pedestrians walking along sidewalks. The trees provide a clearly distinguished barrier between the pedestrian’s and motorist’s space. This enables both to better differentiate between the two areas and remain within their boundaries. If a motorist accidentally crosses into the pedestrian’s space, trees provide a physical barrier protecting pedestrians from fatal impacts by vehicles.

Aesthetically, trees in urban areas camouflage what some would consider unsightly features of urban environments including light poles, utility poles, parked cars, and other structures necessary for urban safety and function. Also, trees create green backdrops that allow for other features of an urban environment to be seen. Properly positioned storefront signs become more dominant and more effectively draw consumer’s attention, leading to increased retail sales. Business with treed storefronts can record a 12% income increase over non-treed storefronts.

7. Risks to Ongoing Benefits

One risk to the Plant a Tree project includes the occurrence of another natural disaster that could destroy some of the trees planted through this project. However, the overall objective of the project is to promote resilience by mitigating effects from future disasters by decreasing wind speeds, resulting in stormwater quantity and quality benefits, and moderating extreme temperatures. While some trees may be lost due to a future disaster, it is expected that the vast majority of planted trees will survive and still achieve the intent of the program.

Another risk to the survival rate of the trees planted under this program is extended drought conditions while the trees are becoming established. However, the project includes an intensive public outreach element that informs residents, business owners, and municipalities about the importance of watering and other needs, and watering agreements are executed with tree recipients to minimize the rate of tree mortality due to poor conditions.

8. Challenges with Implementation

One possible challenge with implementation of the Plant a Tree project is lack of interest or willingness from local residents and/or landlords for installation of tress. In order to increase awareness of the program and buy in, the project includes a strong public outreach component that will utilize bi-lingual (English and Spanish) public relations materials and an implementation template previously developed for the GGCP. Also, the tree planting crews will be working in neighborhoods in Springfield and Greenfield for five years (two years for the public trees and three years for the private trees), with daily contact with residents and property owners. Tree planting crews are hired from the community and adjacent areas, providing employment as well as furthering community connections. They will be working with respected community groups, and will have capacity through staffing and training to assist with potential language and cultural barriers.

The Plant a Tree project also includes a partnership with the local non-profit Re-Green Springfield, which has already worked with EEA and the City of Springfield to plant 1,100 trees in tornado affected neighborhoods via a federal Department of Energy grant in 2012. Re-Green completed outreach and worked with the community to fund an additional 400 trees with local funding in this project. Re-Green will help with local outreach and train crew members so that they become Massachusetts Certified Landscape Professionals while they are in the program, which will greatly help with future arboriculture and landscaping employment in these communities.

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